NFPA®

655

Standard for Prevention of Sulfur Fires and Explosions

2017

NFPA®

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NFPA® 655

Standard for

Prevention of Sulfur Fires and Explosions

2017 Edition

This edition of NFPA 655, *Standard for Prevention of Sulfur Fires and Explosions*, was prepared by the Technical Committee on Handling and Conveying of Dusts, Vapors, and Gases and released by the Correlating Committee on Combustible Dusts. It was issued by the Standards Council on November 11, 2016, with an effective date of December 1, 2016, and supersedes all previous editions.

This edition of NFPA 655 was approved as an American National Standard on December 1, 2016.

Origin and Development of NFPA 655

This standard was first presented to the Association as a progress report in 1938 by the Committee on Dust Explosion Hazards. It was tentatively adopted in 1939. After some revision, it was officially adopted in 1940. Amendments were adopted in 1946, 1947, 1959, 1968, and 1971.

In 1976, responsibility for the document was transferred to the Technical Committee on Fundamentals of Dust Explosion Prevention and Control. The Technical Committee completely revised the 1971 edition to effect minor technical amendments and to editorially revise the document to comply with the NFPA *Manual of Style*.

Due to limited technological changes in this subject area between 1982 and 1988, the Committee reconfirmed the text as it had appeared in the 1982 version. Editorial changes and changes to allow the document to adhere more closely to the 1986 edition of the NFPA *Manual of Style,* were incorporated into the 1988 edition.

For the 1993 edition, the Committee made minor revisions to Chapter 2 for handling finely divided sulfur in bulk and minor revisions to the fire-fighting procedures to be used when fighting fires involving sulfur.

The 2001 edition contained editorial changes associated with incorporation of the 2000 edition of the *Manual of Style for NFPA Technical Committee Documents*. The Committee also made minor revisions to Chapter 6 to address operating precautions for pits and tank sections and to clarify protection for covered liquid sulfur storage tanks.

The 2007 edition included a complete revision of the standard, which was highlighted by the addition of three new chapters and the revision of Chapter 4, which combined the requirements applicable to both finely divided and coarse sulfur. These chapters reflected the Committee's efforts to expand the dust hazard control requirements within the standard. The new chapters—Chapter 7, Fugitive Dust Control and Housekeeping; Chapter 8, Training and Procedures; and Chapter 9, Inspection and Maintenance—were based upon dust hazard evaluation and control processes found in NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids,* 2006 edition. This edition also contained new requirements applicable to intermediate bulk containers (IBCs).

Revisions to the 2012 edition of NFPA 655 focused on updates to the requirements in Chapter 4 for solid sulfur to coordinate with combustible dust hazard assessment and control. Key changes included:

(1) Definitions for *dust flash fire hazard area* and *dust explosion hazard area* were added.
(2) Methods to determine where hazardous dust conditions exist were added to be consistent with NFPA 654.
(3) Housekeeping requirements were updated to include preferred methods and guidance on cleaning frequency.
(4) Requirements for contractors and subcontractors were added.

(5) Personal protection equipment (PPE) requirements related to flash fire hazard protection were added.
(6) Fire-fighting requirements were modified to reflect changes in equipment.
(7) References were updated.
(8) Annex commentary regarding flexible intermediate bulk containers (FIBC) use and cautions against static hazards were added.

For the 2017 edition, revisions include changes to definitions and other material within the standard to correlate with NFPA 654, clarification of the scope of the document and its relationship to NFPA 654, and changes to the requirements for the use of steam in fire fighting.

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Committee Scope: This Committee shall have primary responsibility for documents on the hazard identification, prevention, control, and extinguishment of fires and explosions in the design, construction, installation, operation, and maintenance of facilities and systems used in manufacturing, processing, recycling, handling, conveying, or storing combustible particulate solids, combustible metals, or hybrid mixtures.

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Standard for

Prevention of Sulfur Fires and Explosions

2017 Edition

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Annex A.

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, the complete title and edition of the source documents for extracts in mandatory sections of the document are given in Chapter 2 and those for extracts in informational sections are given in Annex C. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

Information on referenced publications can be found in Chapter 2 and Annex C.

Chapter 1 Administration

1.1 Scope.

1.1.1* This standard addresses the size reduction of sulfur and the handling of sulfur in any form.

1.1.2 This standard shall not apply to the mining of sulfur, recovery of sulfur from process streams, or transportation of sulfur.

1.1.3 This standard shall not apply to the recovery of sulfur from process streams, such as sour gas processing or oil refinery operations, and all its encompassed processes and operations, which include block melting, degassing, and forming.

1.1.4 The owner/operator shall be responsible for implementing the requirements in this standard.

1.1.5* This standard shall be used in conjunction with the requirements of NFPA 654. Where conflicts exist, the requirements of NFPA 655 shall apply.

1.2 Purpose. The purpose of this standard shall be to provide requirements to eliminate or reduce the hazards of explosion and fire inherent in the processing and handling of sulfur.

1.3 Retroactivity. The provisions of this standard reflect a consensus of what is necessary to provide an acceptable degree of protection from the hazards addressed in this standard at the time the standard was issued.

1.3.1 Unless otherwise specified, the provisions of this standard shall not apply to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the standard. Where specified, the provisions of this standard shall be retroactive.

1.3.2 In those cases where the authority having jurisdiction determines that the existing situation presents an unacceptable degree of risk, the authority having jurisdiction shall be permitted to apply retroactively any portions of this standard deemed appropriate.

1.3.3 The retroactive requirements of this standard shall be permitted to be modified if their application clearly would be impractical in the judgment of the authority having jurisdiction, and only where it is clearly evident that a reasonable degree of safety is provided.

1.3.4 This standard shall apply to facilities on which construction is begun subsequent to the date of publication of the standard. When major replacement or renovation of existing facilities is planned, provisions of this standard shall apply.

1.4 Equivalency. Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard.

1.4.1 Technical documentation shall be made available to the authority having jurisdiction to demonstrate equivalency.

1.4.2 The authority having jurisdiction shall be permitted to require that the system, method, or device shall be approved for the intended purpose.

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems,* 2017 edition.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work,* 2014 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting,* 2013 edition.

NFPA 69, *Standard on Explosion Prevention Systems,* 2014 edition.

NFPA 70® , *National Electrical Code®,* 2017 edition.

NFPA 72® , *National Fire Alarm and Signaling Code,* 2016 edition.

NFPA 80, *Standard for Fire Doors and Other Opening Protectives,* 2016 edition.

NFPA *101*®, *Life Safety Code*®, 2015 edition.

NFPA 220, *Standard on Types of Building Construction,* 2015 edition.

NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls,* 2015 edition.

NFPA 600, *Standard on Facility Fire Brigades,* 2015 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids,* 2017 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems,* 2017 edition.

NFPA 2113, *Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Short-Duration Thermal Exposures,* 2015 edition.

2.3 Other Publications.

2.3.1 ISA Publications. International Society of Automation, 67 T.W. Alexander Drive, PO Box 12277, Research Triangle Park, NC 27709.

ANSI/ISA 84.00.01, *Functional Safety: Safety Instrumental Systems for the Process Industry Sector,* 2004 edition.

2.3.2 U.S. Government Publications. U.S. Government Publishing Office, 732 North Capital Street, NW, Washington DC 20401-0001.

Title 29, Code of Federal Regulations, Part 1910. 242(b).

2.3.3 Other Publications.

Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

2.4 References for Extracts in Mandatory Sections.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting,* 2013 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids,* 2017 edition.

NFPA 921, *Guide for Fire and Explosion Investigations,* 2017 edition.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary,* 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3 Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

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3.2.5 Shall. Indicates a mandatory requirement.

3.2.6 Should. Indicates a recommendation or that which is advised but not required.

3.2.7 Standard. An NFPA Standard, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix or annex, footnote, informational note, or other means as permitted in the NFPA Manuals of Style. When used in a generic sense, such as in the phrase "standards development process" or "standards development activities," the term "standards" includes all NFPA Standards, including Codes, Standards, Recommended Practices, and Guides.

3.3 General Definitions.

3.3.1 Deflagration Hazard Area.

3.3.1.1* ***Dust Explosion Hazard Area.*** A room or building volume where an unvented deflagration of the entrainable dust mass can result in a pressure exceeding the strength of the weakest structural element not intended to fail. [**654,** 2017]

3.3.1.2* ***Dust Flash-Fire Hazard Area.*** An area where combustible dust accumulation on exposed or concealed surfaces, external to equipment or containers, can result in personnel injury from thermal dose during a dust deflagration, as well as any areas where a dust cloud of a hazardous concentration exists. [**654,** 2017]

3.3.2 Dust Collector. Any device designed to separate the conveying gas stream from the solid being conveyed.

3.3.3 Explosion. The bursting or rupturing of an enclosure or a container due to the development of internal pressure from a deflagration. [**68,** 2013]

3.3.4* Flash Fire. A fire that spreads by means of a flame front rapidly through a diffuse fuel, such as dust, gas, or the vapors of an ignitible liquid, without the production of damaging pressure. [**921,** 2017]

3.3.5 Intermediate Bulk Containers.

3.3.5.1 ***Flexible Intermediate Bulk Container (FIBC).***

3.3.5.1.1 ***Type A FIBC.*** An FIBC made from nonconductive fabric with no special design features for control of electrostatic discharge hazards. [**654,** 2017]

3.3.5.1.2 ***Type B FIBC.*** An FIBC made from nonconductive fabric where the fabric or the combination of the fabric shell, coating, and any loose liner has a breakdown voltage of less than 6000 volts. [**654,** 2017]

3.3.5.1.3 ***Type C FIBC.*** An FIBC made from conductive material or nonconductive woven fabric incorporating interconnected conductive threads of specified spacing with all conductive components connected to a grounding tab. [**654,** 2017]

3.3.5.1.4 ***Type D FIBC.*** An FIBC made from fabric and/or threads with special static properties designed to control electrostatic discharge energy without a requirement for grounding the FIBC. [**654,** 2017]

3.3.5.2* ***Rigid Intermediate Bulk Container (RIBC).*** An intermediate bulk container (IBC) that can be enclosed in or encased by an outer structure consisting of a steel cage, a single-wall metal or plastic enclosure, or a double wall of foamed or solid plastic. [**654,** 2017]

3.3.5.2.1 ***Insulating RIBC.*** An RIBC constructed entirely of solid plastic or solid plastic and foam composite that cannot be electrically grounded. [**654,** 2017]

3.3.6 Size Reduction Machinery. Any machinery that reduces the size of sulfur particles by grinding, pulverizing, crushing, or similar processes.

3.3.6.1 ***Type 1.*** Low-speed primary crushers, such as jaw and roll crushers.

3.3.6.2 ***Type 2.*** High-speed primary crushers, such as disk and hammer mills, pulverizers, and fine size reduction equipment of all kinds, except Type 4, having a net internal volume of not more than 500 in.^{3} (8193 cm^3).

3.3.6.3 ***Type 3.*** Crushers and pulverizers of the Type 2 category, but having an internal volume of more than 500 in.^{3} (8193 cm^3).

3.3.6.4* ***Type 4.*** Pulverizers that do not depend on moving parts for their disintegrating action, such as attrition mills.

3.3.7* Sulfur Dust. Finely divided sulfur that presents a fire or deflagration hazard when suspended in air or other oxidizing medium over a range of concentrations regardless of particle size or shape.

Chapter 4 Handling Solid Sulfur in Bulk

4.1 General.

4.1.1 This chapter shall apply to the handling and processing of solid sulfur at size reduction facilities.

4.1.2 The objectives in this chapter shall be achieved by either of the following means:

(1) The prescriptive provisions in accordance with this chapter

(2) The performance-based provisions in accordance with Chapter 5 of NFPA 654, and Sections 4.7, 4.8, and 4.9 of this standard

4.1.3 Operation and maintenance of all size reduction machinery shall be under supervision.

4.1.4 Those portions of the size reduction facility where deflagration hazard areas are deemed to exist in accordance with Section 4.2 shall be protected from the effects of these hazards in accordance with Section 4.3 and Chapter 7.

4.2 Identification of Deflagration Hazard Areas.

4.2.1 Those portions of size reduction facility where dust accumulations exist shall be evaluated to determine if a dust explosion hazard or flash-fire hazard exists.

4.2.2 Building, rooms, compartments, and other interior spaces shall be assessed in accordance with 4.2.4 and 4.2.5, unless the colors of the surfaces underlying the dust accumulations are readily discernible.

4.2.3 The process equipment shall be assessed in accordance with 4.2.9.

4.2.4 Dust explosion hazard areas and dust flash-fire hazard areas shall be deemed to exist where dust clouds of a hazardous concentration exist.

4.2.5 Unless the method in 4.2.5.3 is being used, dust explosion hazard areas and dust flash-fire hazard areas shall be deemed to exist when the total accumulated dust on any surfaces exceeds the thresholds calculated in 4.2.5.1 or 4.2.5.2, respectively.

4.2.5.1* The threshold dust mass establishing a building or room as a dust explosion hazard area, $M_{basic\text{-}exp}$, shall be determined according to the following equation:

[4.2.5.1]

$$M_{basic-exp} = 0.01 \cdot A_{floor} \cdot H$$

where:

$M_{basic\text{-}exp}$ = threshold dust mass (kg) based on building damage criterion

A_{floor} = lesser of the enclosure floor area (m^2) or 2000 m^2

H = lesser of the enclosure ceiling height (m) or 12 m

4.2.5.2* The threshold dust mass establishing a building or room as a dust flash-fire hazard area, $M_{basic\text{-}fire}$, shall be determined according to the following equation:

[4.2.5.2]

$$M_{basic-fire} = 0.05 \cdot A_{floor}$$

where:

$M_{basic\text{-}fire}$ = threshold dust mass (kg) based on personnel fire exposure criterion

A_{floor} = lesser of the enclosure floor area (m^2) or 2000 m^2

4.2.5.3 Layer Depth Criterion Method.

4.2.5.3.1* For materials with bulk density less than 75 lb/ft^3 (1200 kg/m^3), the layer depth criterion of $\frac{1}{32}$ in. (0.8 mm) shall be permitted to be increased according to the following equation:

[4.2.5.3.1]

$$\textit{Allowable Thickness}\ (\text{in.}) = \frac{\left(\frac{1}{32}\ \text{in.}\right)\left(75\ \text{lb/ft}^3\right)}{\textit{bulk density}\ \left(\text{lb/ft}^3\right)}$$

4.2.5.3.2 The footprint area shall be determined as the lesser of the building/room area or 21,500 ft^2 (2000 m^2).

4.2.5.3.3* A dust explosion hazard and dust flash-fire hazard shall be deemed to exist in any building or room where either of the following conditions exists:

(1) The total area of dust accumulations exceeding the layer depth criterion is greater than 5 percent of the footprint area.
(2) The total volume of dust accumulations is greater than the layer depth criterion multiplied by 5 percent of the footprint area.

4.2.6 All dust accumulated on structures above the lowest footprint shall be evaluated as if accumulated on the lowest footprint.

4.2.7 Dust accumulation amounts shall reflect the conditions that exist just prior to routinely scheduled cleaning and shall not include short-term accumulations cleaned in accordance with Chapter 7.

4.2.8 Personnel exposed to a dust explosion hazard or dust flash-fire hazard shall be protected in accordance with 8.2.3.

4.2.9 A dust explosion hazard area shall be deemed to exist in process equipment where all the following conditions are possible:

(1) Combustible dust is present in sufficient quantity to cause rupture of the vessel if suspended and ignited.
(2) A means of suspending the dust is present.

4.3 Building Construction.

4.3.1 All buildings shall be of Type I or Type II construction, as defined in NFPA 220.

4.3.1.1 Where local, state, and national building codes are more restrictive, modifications shall be permitted for conformance to these codes.

4.3.1.2* Interior surfaces where dust accumulations can occur shall be designed and constructed so as to facilitate cleaning and to minimize combustible dust accumulations.

4.3.1.3 Spaces inaccessible to housekeeping shall be sealed in order to prevent dust accumulation.

4.3.1.4 Interior walls erected for the purpose of limiting fire spread shall have a minimum 1-hour fire resistance rating and shall be designed in accordance with NFPA 221.

4.3.1.5 Fire Doors.

4.3.1.5.1 Openings in fire walls and in fire barrier walls shall be protected by self-closing fire doors that have a fire resistance rating equivalent to the wall design.

4.3.1.5.2 Fire doors shall be installed according to NFPA 80 and shall normally be in the closed position.

4.3.1.6 Egress. Means of egress shall comply with NFPA *101.*

4.3.1.7 Penetrations. Where floors, walls, ceilings, and other partitions have been erected to control the spread of deflagrations, penetrations in these structures shall be sealed dusttight in normal operation and protected to maintain their fire resistance rating and physical integrity in a deflagration.

4.3.1.8 Fire Resistance Rating.

4.3.1.8.1* Interior stairs and elevators shall be enclosed in shafts designed to prevent the migration of dust and that have a minimum fire resistance rating in accordance with Section 8.6 of NFPA *101.* [**654:**6.3.9.1]

4.3.1.8.2* Doors that are the automatic-closing or self-closing type and that have a minimum fire protection rating of 1 hour shall be provided at each landing. [**654:**6.3.9.2]

4.3.1.8.3 Stairs, elevators, and manlifts that serve only open-deck floors, mezzanines, and platforms shall not be required to be enclosed. [**654:**6.3.9.3]

4.3.1.9* Floor-ceiling assemblies, roof assemblies, and load-bearing walls that are exposed to dust explosion hazards shall be designed so as to preclude failure during an explosion. *(See NFPA 68.)*

4.3.2 Location of Size Reduction Machinery and Containers.

4.3.2.1 Where size reduction machinery is located in an enclosed or partially enclosed space, that space shall be used only for the size reduction process and the filling of containers with the reduced material when size reduction of sulfur is in progress.

4.3.2.2* Containers shall be removed from the area as soon as possible after being filled.

4.3.3 Building Construction Requirements for Housing Size Reduction Machinery.

4.3.3.1 Where Type 1 equipment is located outdoors, it shall be permitted to transfer reduced material in enclosed downstream equipment, provided either of the following conditions exists:

(1) The transferred material is continuously wetted with water sufficient to prevent ignition.
(2) An inert gas isolation system is provided between the Type 1 equipment and the enclosed downstream equipment.

4.3.3.2* Where size reduction machinery is located in an enclosed or partially enclosed space, that space shall be segregated from other areas by noncombustible walls designed to withstand the force of a vented sulfur dust explosion. *(See NFPA 68.)*

4.3.4 Protection of Openings.

4.3.4.1 All pathways between the space used for size reduction and the rest of the building shall be from the outside or via indirect means as described in 4.3.4.2.

4.3.4.2* Indirect pathways through segregating walls by means of vestibules or stairways shall be permitted, provided the wall opening to the size reduction area is protected by an automatic-closing fire door suitable for 3-hour openings, and the opening into the vestibule or stairway is protected by an automatic-closing fire door suitable for 2-hour openings.

4.3.4.2.1 The two automatic-closing fire doors shall be installed at right angles to each other.

4.3.4.2.2 Both fire doors shall be installed in accordance with NFPA 80.

4.3.5 Buildings or enclosures containing a dust explosion hazard area shall be constructed with deflagration venting designed in accordance with NFPA 68.

4.3.6 Horizontal Surfaces.

4.3.6.1 All ledges and surfaces on which dust can accumulate shall be avoided in construction.

4.3.6.2 Where such surfaces cannot be avoided, they shall be filled in or roofed with noncombustible material at an angle of not less than 45 degrees.

4.3.7* Explosion Protection for Equipment. The design of explosion protection for equipment shall incorporate one or more of the methods of protection in 4.3.7(1) through 4.3.7(4).

(1) Oxidant concentration reduction in accordance with NFPA 69 and Section 4.5 of this standard
    (a) Under normal operating conditions, the limiting oxidant concentration (LOC) shall be permitted to be as follows:
        i. 12.0 percent where carbon dioxide is used as the inert
        ii. 9.3 percent where nitrogen is used as the inert
    (b) Where oxygen monitoring is used, it shall be installed in accordance with ANSI ISA 84.00.01, *Functional Safety: Safety Instrumented Systems for the Process Industry Sector*.
(2) Deflagration venting in accordance with NFPA 68
(3) Deflagration pressure containment in accordance with NFPA 69
(4) Deflagration suppression systems in accordance with NFPA 69

4.3.7.1 Dilution with a noncombustible dust to render the mixture noncombustible shall not be permitted.

4.3.7.2 Deflagration venting through a dust retention and flame-arresting device shall not be permitted unless the device is listed for use with sulfur.

4.3.8* Isolation of Equipment.

4.3.8.1* Where an explosion hazard exists, isolation devices shall be provided to prevent deflagration propagation between connected equipment in accordance with NFPA 69.

4.3.8.2 Isolation devices shall not be required where oxidant concentration in the connected equipment has been reduced in accordance with 4.3.7(1) and the general requirements of NFPA 69.

4.3.9* Isolation of Upstream Areas. Where an explosion hazard exists, isolation devices shall be provided to prevent deflagration propagation between connected equipment in accordance with NFPA 69.

4.4* Electrical Wiring and Equipment.

4.4.1 All electrical equipment and installations shall comply with the requirements of *NFPA 70*. [**654:**6.5.1]

4.4.2* In local areas of a plant where a hazardous quantity of dust accumulates or is suspended in air, the area shall be classified and all electrical equipment and installations in those local areas shall comply with Article 502 or Article 503 of *NFPA 70* as applicable. [**654:**6.5.2]

4.4.3 Hazardous (classified) areas that are identified in accordance with 4.4.2 shall be documented, and such documentation shall be permanently maintained on file for the life of the facility. [**654:**6.5.3]

4.5 Inert Gas.

4.5.1 Use of inert gas shall not be required for Type 1 machinery.

4.5.2 Type 2 machinery shall be permitted to be operated without inert gas protection if the following requirements are met:

(1) The feed and discharge shall be provided with isolation devices, such as rotary valves designed in accordance with NFPA 69.
(2) The isolation devices and all machinery between them shall be capable of withstanding an overpressure of 100 lb/in.^{2} (690 kPa).
(3) An inspection of the machinery shall be performed at least once per shift during operation to detect abnormalities in operating conditions.

4.5.3 Type 3 Machinery.

4.5.3.1 Type 3 machinery shall not be operated without the use of an inert gas system meeting the requirements of NFPA 69.

4.5.3.2 Where the pulverized sulfur is removed from the machinery by blower or exhaust systems, inert gas protection shall extend to all piping and collectors.

4.5.3.3* The inert gas system shall be equipped with sampling and recording instruments to obtain a reliable and continuous analysis of the inert atmosphere in that part or parts of the machinery where the inert atmosphere is normally weakest.

4.5.3.4 Provisions shall be made for automatically shutting down the size reduction machinery if the oxygen content of the atmosphere inside the inerted equipment rises above the maximum levels stated in 4.3.7(1).

4.5.4* Type 4 machinery shall be permitted to be operated without inert gas protection if the following requirements are met:

(1) Manually operated valves shall be installed at each machine for control of feed and air lines.
(2)* The equipment shall be under supervision during operation and shall be shut down for detailed inspection and any necessary cleaning when abnormalities in operation indicate the possibility of fire within the machine.
(3) All valves shall be closed before opening the machine.

4.6 Conveyors and Collectors.

4.6.1* Only conveyors or spouts with isolation devices, such as rotary valves designed to prevent deflagration propagation in accordance with NFPA 69 shall be permitted to pass through segregating walls between size reduction rooms and adjacent spaces.

4.6.2 Conveyors used to feed or discharge sulfur to or from size reduction machinery shall be in dusttight housings.

4.6.3 Nonferrous buckets or bucket elevators shall be used where they are housed in ferrous casings.

4.6.4* Aluminum buckets or bucket elevators shall not be used where they are housed in ferrous casings.

4.6.5 Ferrous buckets or bucket elevators shall be permitted to be used with ferrous casings, provided that steam shall be blown into the elevator boot while the elevator is in operation or that an inert gas system meeting the requirements of 4.3.7(1) shall be used.

4.6.6 Unless the conveying system is inerted in accordance with 4.3.7(1), pneumatic conveying of sulfur shall not be permitted.

4.6.7 Each pulverizer shall have a separate and self-contained system.

4.6.8 Dust Collectors.

4.6.8.1 General.

4.6.8.1.1 Location and Protection.

4.6.8.1.1.1 Where an explosion hazard exists, dust collectors with a dirty-side volume of 8 ft^3 (0.2 m^3) or greater shall be located outside of buildings.

4.6.8.1.1.2 For dust collectors that are located outside of buildings, a risk assessment shall be permitted to be conducted to determine the level of explosion protection to be provided.

4.6.8.1.1.3 The requirement of 4.6.8.1.1.1 shall not apply to dust collectors protected in accordance with 4.3.7.

4.6.8.1.2 Where both an explosion hazard and a fire hazard exist in a dust collector, provisions for protection of each type of hazard shall be provided.

4.6.8.1.3 Manifolding of Dust Collection.

4.6.8.1.3.1 Manifolding of dust collection ducts to dust collectors shall not be permitted.

4.6.8.1.3.2 Dust collection ducts from a single piece of equipment or from multiple pieces of equipment interconnected on the same process stream shall be permitted to be manifolded.

4.6.8.1.3.3 Dust collection ducts from nonassociated pieces of equipment shall be permitted to be manifolded provided that each of the ducts is equipped with an isolation device prior to manifolding in accordance with 4.3.8 except as prohibited by 4.6.7.

4.6.8.1.3.4 Dust collection ducts for centralized vacuum cleaning systems shall be permitted to be manifolded.

4.6.8.1.4* Isolation devices shall be provided for dust collectors in accordance with 4.3.8.

4.6.8.1.5* Where lightning protection is provided, it shall be installed in accordance with NFPA 780.

4.6.8.1.6 Exhaust Conveying Gas.

4.6.8.1.6.1 Exhaust conveying gas from the final dust collector shall be discharged outside to a restricted area and away from air intakes.

4.6.8.1.6.2 Conveying gas from dust collectors shall be permitted to be recirculated within enclosed equipment systems.

4.6.8.2 Construction.

4.6.8.2.1 Noncombustible Material.

4.6.8.2.1.1 Dust collectors shall be constructed of noncombustible materials.

4.6.8.2.1.2 Filter media and filter media support structures, where used, shall be permitted to be constructed of combustible material.

4.6.8.2.2 Maximum Material Flow.

4.6.8.2.2.1 Dust collectors shall be constructed so as to minimize internal ledges or other points of dust accumulation.

4.6.8.2.2.2 Hopper bottoms shall be sloped, and the discharge conveying system shall be designed to handle the maximum material flow attainable from the system.

4.6.8.2.3 Access Doors.

4.6.8.2.3.1 Access doors or openings shall be provided to permit inspection, cleaning, and maintenance.

4.6.8.2.3.2 Access doors or openings shall be designed to prevent dust leaks.

4.6.8.2.3.3 Access doors shall be permitted to be used as deflagration vents if they are specifically designed for both purposes.

4.6.8.2.3.4 Access doors shall be bonded and grounded.

4.6.8.2.3.5 Access doors not designed to be used as deflagration vents shall be designed to withstand the vented explosion pressure (P_{red}) in accordance with NFPA 68.

4.7 Prevention of Ignition.

4.7.1 Foreign Materials.

4.7.1.1 Means shall be provided to prevent foreign materials from entering the system when such foreign materials present an ignition hazard.

4.7.1.2 Floor sweepings shall not be returned to any machine.

4.7.1.3* Foreign materials, such as tramp metal, that are capable of igniting sulfur being processed shall be removed from the process stream by one of the following methods:

(1) Permanent magnetic separators or electromagnetic separators that indicate loss of power to the separators
(2) Inerted gas separators
(3) Grates or other separation devices

4.7.2 All machinery shall be installed and maintained in such a manner that the possibility of frictional sparks is minimized.

4.7.3 Interlocking controls shall be installed to stop the dust feed if the size reduction machines stops or if the fans or blowers stop for any reason.

4.7.4* All machinery, conveyors, housings, and collectors shall be thoroughly bonded and grounded with a resistance of less than 1.0×10^6 ohms to ground to prevent the accumulation of static electricity.

4.7.5 Open Flames and Sparks. The requirements of 4.7.5.1 through 4.7.5.3 shall be applied retroactively.

4.7.5.1 Smoking shall be permitted only in designated areas.

4.7.5.2 Activities involving open flames, such as cutting or welding, heat, or hand or power tools, shall be permitted to be made only after all operations have ceased and all sulfur has been removed from the vicinity, protected in tight noncombustible containers, or sufficiently wet with water to prevent ignition.

4.7.5.3 Activities described in 4.7.5.2 shall be controlled by a hot work permit system in accordance with the requirements of NFPA 51B.

4.7.5.4 Heating shall be by indirect means.

4.7.5.5 Unprotected hot surfaces, such as steam lines, that can attain temperatures high enough to melt and ignite sulfur dust shall not be exposed in enclosures housing sulfur processing equipment.

4.7.5.6 Where shovels are used to handle sulfur dust, they shall be nonferrous and spark-resistant.

4.7.6* Propellant-Operated Tools.

4.7.6.1 Propellant-operated tools shall not be used where combustible dust or dust clouds are present.

4.7.6.2 When the use of such tools becomes necessary, all dust-producing machinery in the area shall be shut down; all equipment, floors, and walls shall be cleaned thoroughly; and all accumulations of dust shall be removed.

4.7.6.3 After such work has been completed, a check shall be made to ensure that no cartridges or charges have been left on the premises where they could enter equipment or be accidentally discharged after operation of the dust-producing or dust-handling machinery is resumed.

4.7.6.4 Use of propellant-operated tools shall be controlled by a hot work permit system in accordance with the requirements of NFPA 51B.

4.8* Intermediate Bulk Containers for Solid Sulfur.

4.8.1 The requirements of 4.8.2 through 4.8.4 shall be applied retroactively.

4.8.2* Dispensing solid sulfur from intermediate bulk containers shall only be performed under the following conditions:

(1) A conductive (i.e., metallic) rigid intermediate bulk container (RIBC) shall be permitted to be used for dispensing into any flammable vapor, gas, dust, or hybrid atmospheres provided the RIBC is electrically grounded with a resistance less than 1 megohm to ground.
(2)* A Type C FIBC shall be permitted to be used for dispensing into any flammable vapor, gas, dust, or hybrid atmosphere for which the FIBC has been tested and found suitable, provided the FIBC is electrically grounded with a resistance less than 1 megohm to ground.
(3)* A Type D FIBC shall be permitted to be used for dispensing into flammable vapor, gas, dust, or hybrid atmospheres for which the FIBC has been tested and found suitable.
(4)* Type A FIBC, Type B FIBC, or insulating RIBCs shall not be permitted to be used for solid sulfur applications, processes, or operations unless a documented risk assessment assessing the electrostatic hazards, including the potential presence of hydrogen sulfide, is acceptable to the authority having jurisdiction.

4.8.3* FIBCs that are listed or tested by a recognized testing organization and are shown not to ignite flammable atmospheres, including hydrogen sulfide, during transfer shall be permitted to be used.

4.8.4 Documentation of test results shall be made available to the authority having jurisdiction.

4.9 Fire Fighting.

4.9.1 Where the owner/operator chooses to assign an industrial fire brigade to respond to plant emergencies, the brigade shall meet the requirements of NFPA 600.

4.9.2 Nozzles.

4.9.2.1* Portable spray hose nozzles that are listed or approved for use on Class C fires shall be provided in areas that contain dust, to limit the potential for generating unnecessary airborne dust during fire-fighting operations. [**654:**10.4.2.1]

4.9.2.2 Straight-stream nozzles shall not be used on fires in areas where dust clouds can be generated. [**654:**10.4.2.2]

4.9.2.3* It shall be permitted to use straight stream nozzles or combination nozzles to reach fires in locations that are otherwise inaccessible with the nozzles specified in 4.9.2.1.

4.9.3* Steam and inert gases shall be permitted to be used as extinguishing agents for tightly closed containers provided that the sulfur dust is not disturbed.

4.9.4 In all cases, it shall be made certain that the fire is completely extinguished before disturbing the dust and that the sulfur has cooled sufficiently to prevent reignition.

4.9.5* When size reduction or other processing equipment is opened for cleaning following an ignition, the feed, discharge, and other openings shall first be closed by suitable metal valves or gates.

Chapter 5 Handling of Liquid Sulfur at Normal Handling Temperatures

5.1* General. This chapter shall apply to the handling of liquid sulfur in the temperature range of 246°F to 309°F (119°C to 154°C).

5.2 Detection of Unsafe Conditions.

5.2.1* Devices for measuring the concentration of combustible gas in the atmosphere over liquid sulfur shall be designed for operation in atmospheres containing hydrogen sulfide.

5.2.2 Instruments used for detecting explosive atmospheres shall be capable of measuring the lower explosive limit of hydrogen sulfide, since it is the primary gas evolved from sulfur that can contribute to an explosive atmosphere.

5.2.3 Operations shall be discontinued whenever instruments show a combustible gas concentration of 35 percent or more of the lower explosive limit in the gas space of liquid sulfur containers.

5.2.4 Operations shall not be resumed until the instruments indicate a concentration of 15 percent or less of the lower explosive limit.

5.3 Equipment Design.

5.3.1 Liquid sulfur storage tanks shall be designed with fill lines that extend to near the tank bottom so that the incoming sulfur enters the tank below the surface of the sulfur in the tank, thereby minimizing agitation and release of hydrogen sulfide.

5.3.2 Vent Systems.

5.3.2.1 Covered storage tanks shall be provided with heated vent systems to provide natural venting of hydrogen sulfide.

5.3.2.2 Vent systems shall be maintained at a temperature above the melting temperature of sulfur.

5.3.3* Bonding and Grounding.

5.3.3.1 Sulfur lines and storage tanks shall be bonded and grounded with a resistance of less than 1.0×10^6 ohms to ground to prevent accumulation of static electricity.

5.3.3.2 Grounding connections shall be provided for the bonding of liquid sulfur tanks and tank cars being loaded or unloaded.

5.3.4* In pits or sections of tanks used for melting sulfur, and in liquid storage tanks that are regularly emptied, cooled, and exposed to air (moisture), the sulfur level shall be maintained above the heating coils.

5.3.5* All electrical wiring and equipment installed in areas handling liquid sulfur shall meet the requirements of Article 501 of *NFPA 70* .

5.4 Open Flames and Sparks. The requirements of 5.4.1 through 5.4.3 shall be applied retroactively.

5.4.1 Smoking shall be permitted only in designated areas.

5.4.2 Activities involving open flames, such as cutting or welding, heat, or hand or power tools, shall be permitted to be made only after all operations have ceased and all sulfur has been removed from the vicinity, protected in tight noncombustible containers, or sufficiently wet with water to prevent ignition.

5.4.3 Activities described in 5.4.2 shall be controlled by a hot work permit system in accordance with the requirements of NFPA 51B.

5.5 Fire Fighting.

5.5.1 Protection for covered liquid sulfur storage tanks, pits, and trenches shall be by one of the following means:

(1) Inert gas system in accordance with NFPA 69
(2)* Steam extinguishing system capable of delivering a minimum of 2.5 lb/min (1.13 kg/min) of steam per 100 ft^3 (2.83 m^3) of volume
(3)* Rapid sealing of the enclosure to exclude air

5.5.2 Snuffing Steam and Sealing Steam Precautions.

5.5.2.1 The vent systems on enclosed sulfur tanks and sulfur pits shall be designed to allow the required snuffing steam rate or sealing steam rate to vent without overpressuring the enclosure.

5.5.2.2 The vent systems shall also be designed for proper operation during normal operation.

5.5.3 Water Extinguishing Precautions.

5.5.3.1 Liquid sulfur stored in open containers shall be permitted to be extinguished with a fine water spray.

5.5.3.2 Use of high-pressure hose streams shall be avoided.

5.5.3.3 The quantity of water used shall be kept to a minimum.

5.5.4 Dry Chemical Extinguishers. Where sulfur is being heated by a combustible heat transfer fluid, dry chemical extinguishers complying with NFPA 17 shall be provided.

Chapter 6 Handling of Liquid Sulfur and Sulfur Vapor at Temperatures Above 309°F (154°C)

6.1 General.

6.1.1 This chapter shall apply to liquid sulfur and its vapors when heated in closed containers to temperatures above 309°F (154°C).

6.1.2 The requirements of Chapter 5 shall apply.

6.2 Operating Precautions and Equipment Design.

6.2.1 Equipment shall be designed to be closed as tightly as possible to prevent escape of vapor and to exclude air from the system during operation.

6.2.2 Deflagration Venting.

6.2.2.1 Process equipment shall be provided with deflagration venting, in accordance with NFPA 68.

6.2.2.2 Where vent ducts are required, the vent pipes or ducts shall be heated to prevent condensation of sulfur vapor.

6.2.3 An adequate supply of a suitable inerting agent such as steam shall be available at all times for blanketing and purging equipment.

6.2.4 All buildings or enclosures for such processes shall comply with 4.3.1, 4.3.1.1, and 4.3.1.4 through 4.3.1.8.

6.2.5 Where sulfur is vaporized and subsequently condensed to sulfur dust, handling of the finely divided sulfur from the process shall comply with the requirements of Chapter 4.

Chapter 7 Fugitive Dust Control and Housekeeping

7.1 Fugitive Dust Control.

7.1.1* Continuous suction shall be provided for processes where combustible dust is liberated in normal operation so as to minimize the escape of dust.

7.1.2 The dust shall be conveyed to dust collectors.

7.2 Housekeeping. The requirements of 7.2.1 through 7.2.3 shall be applied retroactively.

7.2.1 Cleaning Frequency.

7.2.1.1* Where the facility is intended to be operated with less than the dust accumulation defined by the thresholds in Section 4.2, the housekeeping frequency shall be established to ensure that the accumulated dust levels on walls; on floors; on horizontal surfaces, such as equipment, ducts, pipes, hoods, ledges, and beams; and above suspended ceilings and other concealed surfaces, such as the interior of electrical enclosures, does not exceed the threshold dust accumulation.

7.2.1.2* Where the facility is intended to be operated with less than the dust accumulation defined by the thresholds in Section 4.2, a planned inspection process shall be implemented to evaluate dust accumulation rates and the housekeeping frequency required to maintain dust accumulations below the threshold dust accumulation.

7.2.1.3 Where the facility is intended to be operated with more than the dust accumulation defined by the thresholds in Section 4.2, a documented risk assessment acceptable to the authority having jurisdiction shall be conducted to determine the level of housekeeping consistent with any dust flash-fire and dust explosion protection measures provided in accordance with Section 4.3 and Chapter 8.

7.2.2 Cleaning.

7.2.2.1 Surfaces shall be cleaned in a manner that minimizes the generation of dust clouds.

7.2.2.2* Sweeping shall be the preferred method.

7.2.2.3 Vacuuming shall be permitted.

7.2.2.4* Blowdowns using compressed air or steam shall be permitted to be used for cleaning inaccessible surfaces or surfaces where other methods of cleaning result in greater personal safety risk. Where blowdowns are performed, the following precautions shall be followed:

(1) Sweeping or vacuum cleaning methods are first used to clean surfaces that can be safely accessed prior to blowing down.
(2) Dust accumulations in the area after sweeping or vacuum cleaning do not exceed the threshold dust accumulation.
(3) Where compressed air is used, hoses are equipped with pressure relief nozzles limiting the discharge pressure to a gauge pressure of 30 psi (207 kPa) in accordance with OSHA requirements 29 CFR 1910.242(b).
(4) All electrical equipment potentially exposed to airborne dust in the area meets, as a minimum, *NFPA 70* dusttight requirements, or equivalent.
(5) All ignition sources and hot surfaces capable of igniting a dust cloud or dust layer are shut down or removed from the area.

7.2.2.5 Housekeeping procedures shall be documented.

7.2.3 Vacuum Cleaners.

7.2.3.1 Vacuum cleaners shall be listed for use in Class II hazardous locations or shall be a fixed-pipe suction system with remotely located exhauster and dust collector installed in conformance with 4.6.8.

7.2.3.2 Where flammable vapors or gases are present, vacuum cleaners shall be listed for Class I and Class II hazardous locations.

Chapter 8 Training and Procedures

8.1 Employee Training. The requirements of Chapter 8 shall be applied retroactively.

8.2 Plan.

8.2.1 Operating and maintenance procedures and emergency plans shall be developed. [**654:**11.2.1]

8.2.2 A written emergency response plan shall be developed for preventing, preparing for, and responding to work-related emergencies including but not limited to fire and explosion. [**654:**11.2.2]

8.2.3 Operating and maintenance procedures shall address personal protective equipment (PPE) for tasks involving processing or handling of combustible dust according to the following:

(1) PPE shall include flame-resistant garments if determined necessary by a workplace hazard assessment conducted in accordance with NFPA 2113.
(2) Where a dust explosion hazard or dust flash-fire hazard exists, flame-resistant garments shall be required for all exposed personnel.

8.2.4 The plans and procedures shall be reviewed annually and as required by process changes. [**654:**11.2.4]

8.3 Initial and Refresher Training.

8.3.1 Initial and refresher training shall be provided to employees who are involved in operating, maintaining, and supervising facilities that handle combustible particulate solids. [**654:**11.3.1]

8.3.2 Initial and refresher training shall ensure that all employees are knowledgeable about the following:

(1) Hazards of their workplace
(2) General orientation, including plant safety rules
(3) Process description
(4) Equipment operation, safe start-up and shutdown, and response to upset conditions
(5) The necessity for related fire and explosion protection systems to function as designed and installed
(6) Equipment maintenance requirements and practices
(7) Housekeeping requirements
(8)* Emergency response plans

[**654:**11.3.2]

8.4 Certification. The employer shall certify annually that the training and review required by Sections 8.2 and 8.3 have been completed.

8.5 Contractors and Subcontractors.

8.5.1 The owner/operator shall ensure that the requirements of 8.5.1.1 through 8.5.4 are met.

8.5.1.1* Only qualified contractors possessing the requisite craft skills shall be employed for work involving the installation, repair, or modification of buildings (interior and exterior), machinery, and fire protection equipment. [**654:**11.5.1.1]

8.5.1.2 Contractors involved in the commissioning, repair, or modification of explosion protection equipment shall be qualified as specified in Chapter 15 of NFPA 69 when such devices are employed.

8.5.2 Contractor Training.

8.5.2.1 Contractors operating owner/operator equipment shall be trained and qualified to operate the equipment and perform the work. [**654:**11.5.2.1]

8.5.2.2 Written documentation shall be maintained detailing the training that was provided and who received it. [**654:**11.5.2.2]

8.5.3 Contractors working on or near a given process shall be made aware of the potential hazards from and exposures to fire, explosion, or toxic releases. [**654:**11.5.3]

8.5.4* Contractors shall be trained and required to comply with the facility's safe work practices and policies, including but not limited to equipment lockout/tagout permitting, hot work permitting, fire system impairment handling, smoking, housekeeping, and use of PPE. [**654:**11.5.4]

Chapter 9 Inspection and Maintenance

9.1 General. The requirements of 9.1.1 through 9.1.3 shall be applied retroactively.

9.1.1 An inspection, testing, and maintenance program shall be developed and implemented to ensure that the fire and explosion protection systems and related process controls and equipment perform as designed.

9.1.2 The inspection, testing, and maintenance program shall include the following:

(1) Fire and explosion protection and prevention equipment in accordance with the applicable NFPA standards
(2) Dust control equipment
(3) Housekeeping
(4) Potential ignition sources
(5)* Electrical, process, and mechanical equipment, including process interlocks
(6) Process changes
(7) Lubrication of bearings

9.1.3 Records shall be kept of maintenance and repairs performed.

9.2 Specific Equipment Maintenance.

9.2.1 Maintenance of Material-Feeding Devices.

9.2.1.1 Bearings shall be lubricated in accordance with manufacturer's recommendations and checked for excessive wear on a periodic basis.

9.2.1.2 If the material has a tendency to adhere to the feeder or housing, these components shall be cleaned periodically to maintain good balance and minimize the probability of ignition.

9.2.2 Maintenance of Fan and Blowers.

9.2.2.1 Fans and blowers shall be checked periodically for excessive heat and vibration.

9.2.2.2 Maintenance, other than the lubrication of external bearings, shall not be performed on fans or blowers while the unit is operating.

9.2.2.3 Bearings shall be lubricated in accordance with manufacturer's recommendations and checked periodically for excessive wear.

9.2.2.4* If the material has a tendency to adhere to the rotor or housing, these components shall be cleaned periodically to maintain good balance and minimize the probability of ignition.

9.2.2.5* The surfaces of fan housings and other interior components shall be maintained free of rust.

9.2.2.6 Aluminum paint shall not be used on interior steel surfaces.

9.2.3 Maintenance of Dust Collectors.

9.2.3.1 Means to Dislodge.

9.2.3.1.1 Dust collectors that are equipped with a means to dislodge particulate from the surface of filter media shall be inspected periodically as recommended in the manufacturers' instructions for signs of wear, friction, or clogging.

9.2.3.1.2 These devices shall be adjusted and lubricated accordingly as recommended in the manufacturers' instructions.

9.2.3.2 Filter media shall not be replaced with an alternate type unless a thorough evaluation of the fire hazards has been performed, documented, and reviewed by management.

9.2.4 Maintenance of Fire and Explosion Protection Systems.

9.2.4.1 All fire detection equipment monitoring systems shall be maintained in accordance with the requirements of *NFPA 72* .

9.2.4.2 All fire extinguishing systems shall be maintained pursuant to the requirements established in the standard that governs the design and installation of the system.

9.2.4.3 All vents for the relief of pressure caused by deflagrations shall be maintained in accordance with NFPA 68.

9.2.4.4 All explosion prevention systems and inerting systems shall be maintained pursuant to the requirements of NFPA 69.

Annex A Explanatory Material

Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.1.1.1 Sulfur differs from most other combustible dusts found in industry in that it has relatively low melting and ignition points. Depending on purity, sulfur melts at or slightly below 246°F (119°C). The ignition temperature of a dust cloud is 374°F (190°C); the ignition temperature of a dust layer is 428°F (220°C). Dilution of sulfur with inert solids is not effective in raising the ignition temperature. Sulfur is handled and processed in the liquid and vapor states in some cases. The liquid is highly combustible, and the vapor is explosive when mixed with air in the proper proportions.

The finely divided sulfur produced during size reduction and size reduction is the most hazardous from an explosion standpoint. Also, mixtures containing finely divided elemental sulfur can be just as hazardous if the sulfur is present in sufficient quantity. Some explosion and fire hazards also accompany the handling and processing of sulfur in bulk in coarse sizes due to the fine dust present.

A.1.1.5 This standard has been historically used to supplement the requirements of NFPA 654. It will continue to do so for the next revision cycle as NFPA 654 becomes aligned with NFPA 652.

A.3.2.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction (AHJ). The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.3.2.4 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A.3.3.2.1 Dust Explosion Hazard Area. See NFPA 68 for evaluating strength of enclosures.

A.3.3.2.2 Dust Flash-Fire Hazard Area. Where the dust cloud concentration is equal to or greater than the MEC, it poses a dust explosion and dust flash-fire hazard. A propagating deflagration yields a flash fire through the hazard area. In *Dust Explosions in the Process Industries*, Eckhoff observes for coal dust that if the cloud obscures a 25 W lightbulb over a 6.6 ft (2 m) length, the concentration is probably close to the MEC. It is customary to consider a dust cloud hazardous when the concentration exceeds 25 percent of the MEC. It is recognized that it is often very difficult or impractical to measure airborne dust concentration in this range in an industrial setting. For this reason, it is often necessary to rely on subjective measures to determine the dust cloud concentration. [**654,** 2017]

A.3.3.4 Flash Fire. A flash fire requires an ignition source and a hydrocarbon or an atmosphere containing combustible, finely divided particles (e.g., coal dust or grain) having a concentration greater than the lower explosive limit of the chemical. Both hydrocarbon and dust flash fires generate temperatures from 1000°F to 1900°F (538°C to 1038°C). The intensity of a flash fire depends on the size of the gas, vapor, or dust cloud. When ignited, the flame front expands outward in the form of a fireball. The resulting effect of the fireball's energy with respect to radiant heat significantly enlarges the hazard areas around the point of ignition.

A.3.3.5.2 Rigid Intermediate Bulk Container (RIBC). These are often called *composite IBCs*, which is the term used by U.S. Department of Transportation (DOT). The term *rigid nonmetallic intermediate bulk container* denotes an all-plastic single-wall IBC that might or might not have a separate plastic base and for which the containment vessel also serves as the support structure. [**654,** 2017]

A.3.3.6.4 Type 4. The size reduction in Type 4 machines is accomplished by attrition of the particles on themselves. Power for moving the particles is furnished by compressed air or other fluid suitable to the material being pulverized.

A.3.3.7 Sulfur Dust. The Committee is aware of data contained in Eckhoff, *Dust Explosions in the Process Industries*, Table A1, which reported positive explosion test results of a sulfur dust cloud with a median particle size of 120 µm as being explosible.

A.4.2.5.1 Figure A.4.2.5.1 shows layer thicknesses equivalent to the threshold dust masses according 4.2.5.1. As an example of the use of Figure A.4.2.5.1 or the equations, the user would initially determine the fractional areas within the facility where significant dust accumulation is occurring or could occur. Using the equations or the chart, the allowable mass would be determined and then converted to an equivalent layer thickness that can be incorporated into the user's routine housekeeping procedure, as required by Chapter 7. Ongoing cleaning would then ensure that the layer thickness within the defined areas of significant dust accumulation was maintained less than the thicknesses determined in the initial assessment.

A.4.2.5.2 See A.4.2.5.1.

A.4.2.5.3.1 The layer depth criterion would be approximately 1⁄16 in. (1.7 mm) based on a typical bulk density of rubbermakers sulfur (45 lb/ft^3 [720 kg/m^2]). If the sulfur at the facility has a different bulk density, the thickness should be corrected for that specific bulk density.

A.4.2.5.3.3 A relatively small initial dust deflagration can disturb and suspend in air dust that has been allowed to accumulate on the flat surfaces of a building or equipment. This dust cloud provides fuel for the secondary deflagration, which can cause damage. Reducing significant additional dust accumulations is therefore a major factor in reducing the hazard in areas where a dust hazard can exist.

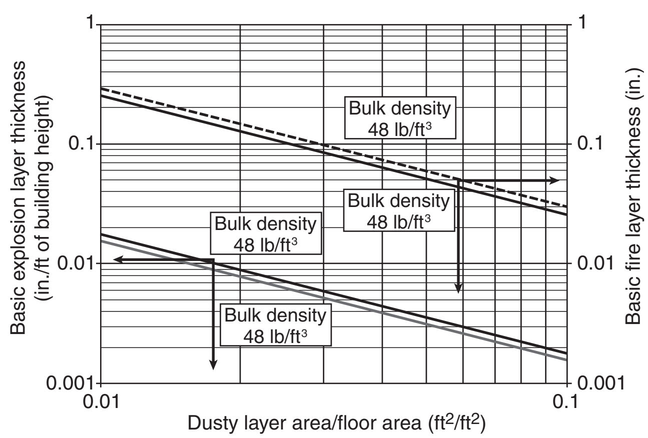

FIGURE A.4.2.5.1 Layer Thicknesses Equivalent to the Threshold Dust Masses.

Using a bulk density of 45 lb/ft^3 (720 kg/m^3), it has been calculated that a dust layer averaging $\frac{1}{16}$ in. (1.7 mm) thick and covering the floor of a building is sufficient to produce a uniform dust cloud of 0.37 oz/ft^3 (370 g/m^3) 10 ft (3 m) high throughout the building. This is a conservative value for the optimum concentration with respect to explosion damage potential. This situation is idealized, and several factors should be considered.

First, the layer rarely will be uniform or cover all surfaces. Second, the layer of dust probably will not be dispersed completely by the turbulence of the pressure wave from the initial explosion. However, if only 50 percent of the $\frac{1}{16}$ in. (1.7 mm) thick layer is suspended, this material is still sufficient to create an atmosphere within the explosible range of sulfur dusts.

Consideration should be given to the proportion of building volume that could be filled with a combustible dust concentration. The percentage of floor area covered can be used as a measure of the hazard. For example, a 10 ft × 10 ft (3 m × 3 m) room with a $\frac{1}{16}$ in. (1.7 mm) layer of dust on the floor is obviously hazardous and should be cleaned. This same 100 ft^2 (9.3 m^2) area in a 2025 ft^2 (188 m^2) building is also a moderate hazard. This area represents about 5 percent of the floor area and is about as much coverage as should be allowed in any plant. To gain proper perspective, the overhead beams and ledges also should be considered. Rough calculations show that the available surface area of the bar joist is about 5 percent of the floor area. For steel beams, the equivalent surface area can be as high as 10 percent.

From the preceding information, the following guidelines have been established:

(1) Dust layers $\frac{1}{16}$ in. (1.7 mm) thick can be sufficient to warrant immediate cleaning of the area.
(2) The dust layer is capable of creating a hazardous condition if it exceeds 5 percent of the building floor area.
(3) Dust accumulation on overhead beams and joists contributes significantly to the secondary dust cloud and is approximately equivalent to 5 percent of the floor area. Other surfaces, such as the tops of ducts and large equipment, can also contribute significantly to the dust cloud potential.
(4) Due consideration should be given to dust that adheres to walls, since it is easily dislodged.
(5) Attention and consideration should be given to projections such as light fixtures, which can provide surfaces for dust accumulation.
(6) Dust collection equipment should be monitored to ensure that it is operating effectively. For example, dust collectors using bags operate most effectively between limited pressure drops of 2 in. to 5 in. of water (0.5 kPa to 1.24 kPa).

Guidelines (1) through (5) serve to establish a cleaning frequency.

A.4.3.1.2 Window ledges, girders, beams, and other horizontal projections or surfaces can have the tops sharply sloped, or other provisions can be made to minimize the deposit of dust thereon. Overhead steel I-beams or similar structural shapes can be boxed with concrete or other noncombustible material to eliminate surfaces for dust accumulation. Surfaces should be as smooth as possible to minimize dust accumulations and to facilitate cleaning.

A.4.3.1.8.1 An appropriate test method is ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*. [**654:**A.6.3.9.1]

A.4.3.1.8.2 An appropriate test method is in accordance with NFPA 252. [**654:**A.6.3.9.2]

A.4.3.1.9 The use of load-bearing walls should be avoided to prevent structural collapse should an explosion occur.

A.4.3.2.2 It is not the intent of this requirement to prohibit interim storage of bags, drums, or filled containers.

A.4.3.3.2 It is preferable that the size reduction space be detached. Exterior walls could require explosion venting. Steel frame construction, with light, nonbearing exterior walls and a light roof, is preferable.

A.4.3.4.2 It is recommended that an emergency escapeway for personnel be provided independently.

A.4.3.7 Pre-deflagration detection and control systems can be applied where installed in accordance with NFPA 69. However, a pre-deflagration detection and control system should not be used as the primary explosion prevention device. In addition, users are cautioned that infrared or near-infrared detectors are not effective on sulfur fires.

A.4.3.8 Methods of explosion protection using containment, venting, and suppression protect the specific process equipment on which they are installed. Flame fronts from a deflagration can propagate through connecting ductwork to other unprotected process equipment and to the building from outside process equipment. Figure A.4.3.8 shows an example of how this propagation might occur. Isolation techniques as shown in Figure A.4.3.8.1(a) through Figure A.4.3.8.1(d) can be used to prevent the propagation of the deflagration by arresting the flame front.

Both the direction and extent of potential deflagration propagation must be considered. Usually, a dust deflagration occurs in a fuel-rich regime (i.e., above the stoichiometric fuel-air ratio), making it likely that the initial deflagration will expand into volumes that are many times greater than the initial deflagration volume.

The dynamics of a dust explosion are such that unburned dust is pushed ahead of the flame front by the expanding products of combustion. This dust is expelled from the containment vessel via every available exit path, in all possible directions of flow, including flow via all connecting ducts and out through any provided explosion venting. The driving force pushing the dust away from the point of initiation (which, under vented conditions, might be in the range of a few pounds per square inch) can easily overcome the force of normal system flow (which typically might be of the order of a few inches water column). Furthermore, the velocities produced by the deflagration usually greatly exceed those of the pneumatic conveying system under normal design conditions. Consequently, unburned dust and the deflagration flame front can be expected to propagate upstream through ductwork from the locus of the initial deflagration.

The conveyance of the flame front via both the in-feed and outflow ducts should be evaluated. In most cases, this movement of dust and propagating flame front will commute the deflagration to the connected equipment via ductwork. Where equipment and ducts are adequately protected pursuant to this standard and NFPA 68 (where explosion venting is used), the consequences of explosion propagation might not increase the life safety hazard or significantly increase the property damage. However, in other cases, the transit of a deflagration flame front does result in substantial increases in the severity of an event.

In the case of several pieces of equipment connected via ductwork, where each piece of equipment and the ductwork are provided with explosion venting, the dust explosion can nevertheless propagate throughout the system. Explosion venting on the equipment of deflagration origin will prevent overpressure damage to that vessel. If the concentration within the connecting ductwork is below the minimum explosible concentration (MEC) prior to the deflagration, the deflagration can still spread to the next vessel, but the explosion venting there should protect that second vessel from overpressure damage. In such a case, the provision of explosion isolation would not provide any significant reduction in either the property damage or life safety hazard.

If the concentration within a connecting duct is above the MEC prior to the deflagration, then the propagation through that duct will result in an accelerating flame front. Without explosion venting on the ductwork, this accelerating flame front will result in a significant prepressurization of the equipment at the other end of the duct and in a very powerful jet flame ignition of a dust deflagration within that second vessel. Such a deflagration can overwhelm the explosion venting on that vessel, even if the design is based on information in NFPA 68, resulting in the catastrophic rupture of the vessel. In this case, the explosion propagation results in a significant increase in the property damage and, quite possibly, in an increase in life safety hazard due to the vessel rupture. Consequently, explosion isolation is a critical component to the management of the fire and explosion risk.

In the case of a dust collector serving a large number of storage silos, an explosion originating in the dust collector can produce an acceptable level of damage to the collector if it is provided with adequate explosion venting per NFPA 68. However, the propagation of that explosion upstream to all the connected silos could cause ignition of the material stored in all those silos. The initiation of such storage fires can significantly escalate the magnitude of the incident, in terms of property damage, interruption to operations, and life safety hazard. As with the previous example of a connecting duct having a concentration above the MEC prior to deflagration, explosion isolation would be warranted in this case.

A.4.3.8.1 When rotary valves are installed in both the inlet and outlet of equipment, care should be taken to ensure that the rotary valve on the inlet is stopped before the unit becomes overfilled. See Figure A.4.3.8.1(a) for an example of rotary valves.

Figure A.4.3.8.1(b) illustrates one example of deflagration propagation using mechanical isolation.

Figure A.4.3.8.1(c) illustrates one example of deflagration propagation using flame front diversion.

Figure A.4.3.8.1(d) illustrates one example of deflagration propagation using chemical isolation.

A.4.3.9 Exposures of concern include, but are not limited to, bagging operations and hand-dumping operations, in which the discharge of a fireball from the pickup point would endanger personnel.

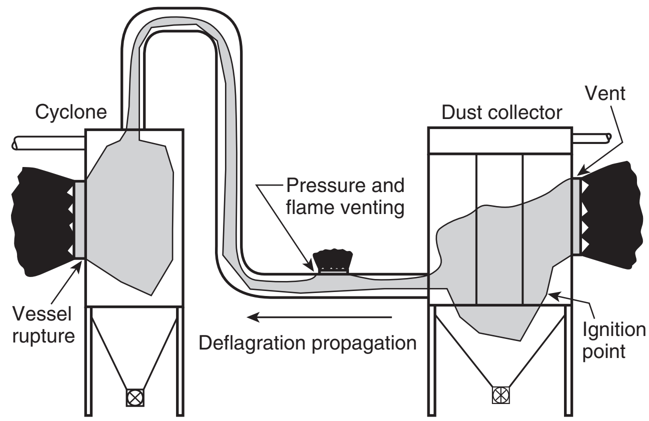

FIGURE A.4.3.8 An Example of Deflagration Propagation Without Isolation. [654: Figure E.1]

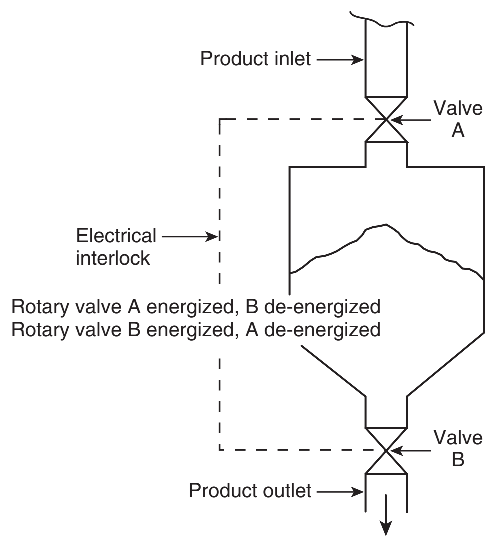

FIGURE A.4.3.8.1(a) Rotary Valves.

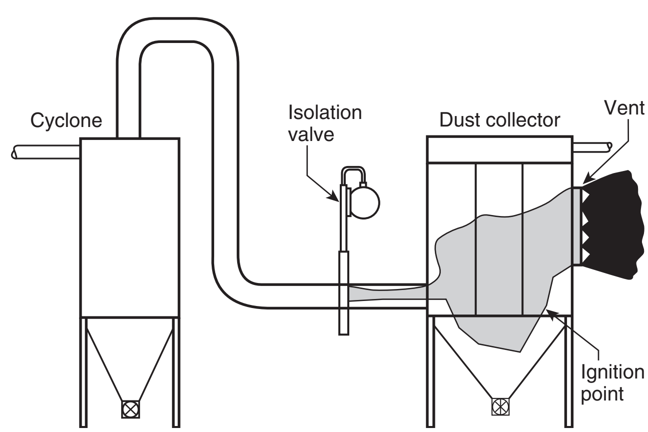

FIGURE A.4.3.8.1(b) Deflagration Propagation Using Mechanical Isolation.

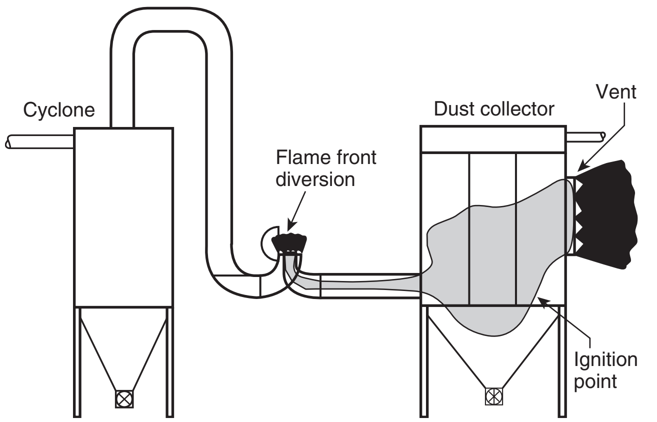

FIGURE A.4.3.8.1(c) Deflagration Propagation Using Flame Front Diversion.

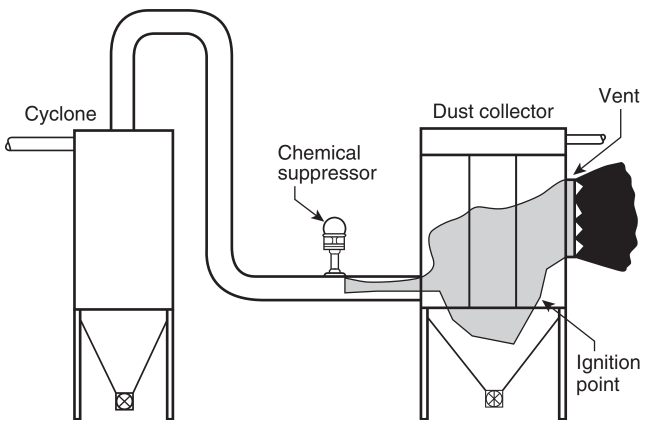

FIGURE A.4.3.8.1(d) Deflagration Propagation Using Chemical Isolation.

A common example for the application of such isolation would be in the upstream duct work associated with a dust collection system servicing a work area. Loading chutes less than 10 ft (3 m) in length and designed for gravity flow are not considered duct work. Due to a high likelihood of ignition of sulfur dust, dust collectors should be operated under inert atmosphere.

A.4.4 Although sulfur is not now included in atmospheres classified as Class II, Group G, it has been the experience of the sulfur industry that such equipment can be suitable. However, consideration should be given to the melting point of sulfur, 233°F to 246°F (112°C to 119°C), in the selection of heat-producing electrical equipment.

A.4.4.2 Refer to NFPA 499. Table A.4.4.2 provides guidance for area electrical classification.

A.4.5.3.3 Auxiliary instrumentation should be provided for sampling and recording the quality of the inert atmosphere in other parts of the system.

A.4.5.4 The large volumes and high velocities of air and the compactness of the Type 4 unit make inerting usually impractical.

A.4.5.4(2) Flooding with inert gas or steam, combined with delayed opening to permit smothering of any residual fire, is recommended.

A.4.6.1 Screw conveyors and conveyors in general can be used for applications other than explosion isolation.

A.4.6.4 This restriction is not intended to preclude the use of any or all aluminum components, but it should be understood to apply to components in relative motion with each other. The reaction of a metal with the oxide of a different metal is called a thermite reaction. The reactants provide their own oxygen supply and thus present a high fire risk. An example of this is the reaction of aluminum with ferric oxide (rust), where the products would be aluminum oxide and free elemental iron. The rubbing of aluminum metal buckets against a rusted surface will first commingle the aluminum with the ferric oxide and with continued rubbing generate sufficient heat to initiate the reaction and provide an ignition source for the combustible dust in the bucket elevator. For more information, see Hawley, *Condensed Chemical Dictionary*.

A.4.6.8.1.4 For design requirements for fast-acting dampers and valves, flame front diverters, and flame front extinguishing systems, see NFPA 69.

A.4.6.8.1.5 Annex L.6 of NFPA 780 and IEC 62305-2, *Protection Against Lightning — Part 2: Risk Management*, provide methods for assessments to determine the need for lightning protection.

A.4.7.1.3 It should be recognized that magnetic separators will not remove nonferrous tramp material, including stones, brick, and concrete. Every care, using other means, should be taken to ensure excluding such materials from the size reduction system.

A.4.7.4 See NFPA 77 for information on the subject.

A.4.7.6 Propellant-operated tools include all of the following:

(1) Cartridge operated
(2) Powder operated
(3) Tools using combustible gas as the propellant

A.4.8 For further information regarding the hazards and uses of flexible and rigid intermediate bulk containers, see Section 9.1 of NFPA 77 and *Avoiding Static Ignition Hazards in Chemical Operations*, pp. 199–204.

A.4.8.2 Unless intentionally removed by the process, sulfur typically contains adsorbed hydrogen sulfide. Dispensing generates static charge, which can ignite not only the combustible dust atmosphere but also the hydrogen sulfide. Minimum ignition energy (MIE) of less than 1 mJ has been reported for particulate sulfur, while MIE of 0.068 mJ has been reported for hydrogen sulfide. MIEs are measured in accordance with ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*.

A.4.8.2(2) Due to the particularly low MIE of hydrogen sulfide, the suitability of specific manufacturers' Type C FIBCs in the presence of hydrogen sulfide atmospheres should be determined. Failure to provide grounding for a Type C FIBC can create a potential static discharge hazard greater than using Type A or Type B FIBCs.

A.4.8.2(3) Due to the particularly low MIE of hydrogen sulfide, the suitability of specific manufacturers' Type D FIBCs in the presence of hydrogen sulfide atmospheres should be determined.

Table A.4.4.2 Guidance for Area Electrical Classification

Depth of Dust Accumulation (in.)	Frequency	Housekeeping Requirement	Area Electrical Classification
Negligible[a]	N/A	N/A	Unclassified (general purpose)
Negligible to <1/32 [b]	Infrequent[c]	Cleanup during same shift.	Unclassified (general purpose)
Negligible to <1/32 [b]	Continuous/frequent[d]	Clean as necessary to maintain an average accumulation below 1/64 in.[e]	Unclassified; however, electrical enclosures should be dusttight. [f, g]
1/32 to 1/8	Infrequent[c]	Cleanup during same shift.	Unclassified; however, electrical enclosures should be dusttight. [f, g]
1/32 to 1/8	Continuous/frequent[d]	Clean as necessary to maintain an average accumulation below 1/16 in.	Class II, Division 2
>1/8	Infrequent[c]	Immediately shut down and clean.	Class II, Division 2
>1/8	Continuous/frequent[d]	Clean at frequency appropriate to minimize accumulation.	Class II, Division 1

For SI units, 1 in. = 25.4 mm.
Note: This table does not apply to Class III materials.
[a]Surface color just discernible under the dust layer.
[b] 1/32 in. is approximately the thickness of a typical paper clip.
[c]Episodic release of dust occurring not more than about two or three times per year.
[d]Episodic release of dust occurring more than about three times per year or continuous release resulting in stated accumulation occurring in approximately a 24-hour period.
[e]It has been observed that a thickness of about 1/64 in. of a low-density dust is sufficient to yield a small puffy cloud with each footstep.
[f]For example, National Electrical Manufacturers Association (NEMA) 12 or better. Note: Ordinary equipment that is not heat producing, such as junction boxes, can be significantly sealed against dust penetration by the use of silicone-type caulking. This can be considered in areas where fugitive dust is released at a slow rate and tends to accumulate over a long period of time.
[g]Guidance to be applied for existing facilities. For new facilities, it is recommended that the electrical classification be at least Class II, Division 2.
[**654:** Table A.6.5.2]

A.4.8.2(4) The use of Type A or Type B FIBCs and insulating RIBCs should be based on a documented risk assessment acceptable to the authority having jurisdiction. Type A and Type B FIBCs and insulating RIBCs can generate sufficient electrostatic energy discharge to ignite ground or crushed sulfur powder (i.e., powders with MIE values = 3 mJ). Dry sulfur can be delivered as formed sulfur (prills, flakes, granules, and pastilles) as well as powders. Attrition through normal handling could produce fines. Larger forms of sulfur generally would be expected to have higher MIE values, which should be determined by test in accordance with ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*, or similar international protocol, and might allow the use of Type A or Type B FIBCs and insulating RIBCs. The determination of the suitability of Type A or Type B FIBCs and insulating RIBCs should be based not only on MIE but also on electrostatic properties, such as electrostatic chargeability and volume resistivity tested in general accordance with ASTM D257, *Standard Test Methods for DC Resistance or Conductance of Insulating Materials*, and MEC tested in accordance with ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, or similar international protocol. The evaluation should also consider sulfur-handling and sulfur-processing operations prior to FIBC filling and unloading. Generally speaking, faster filling and unloading rates (such as with pneumatic conveying) would be expected to generate higher levels of static charge and should be avoided. If fines with MIE = 3 mJ are present in sufficient quantity to form a suspended dust cloud of sufficient concentration to support a deflagration, as determined in accordance with ASTM E1515 [typically 0.035 oz/ft^3 (35 g/m^3)], then there is sufficient risk to preclude the use of Type A or Type B FIBCs and insulating RIBCs.

A.4.8.3 Certain fabrics that pose significantly less risk of ignition in flammable atmospheres have been developed for use in FIBCs. One such fabric that has been tested for use in flammable atmospheres and has been used in FIBCs is documented in Ebadat and Mulligan, "Testing the Suitability of FIBCs for Use in Flammable Atmospheres."

A.4.9.2.1 A nozzle listed or approved for use on Class C fires produces a spray discharge pattern that is less likely than a straight stream nozzle to suspend combustible dust, which could produce a dust explosion potential.

A.4.9.2.3 Where a straight stream must be used to reach fires in inaccessible locations, the stream should be directed above the burning material so that the water rains down on the material.

A.4.9.3 If a container is tightly closed and the volume of oxygen enclosed is not too large, a fire will be smothered by the sulfur dioxide formed. When steam is used for fire suppression in enclosed equipment, the rate of application should be at least 2.5 lb/min/100 ft^3 (1.13 kg/min/2.83 m^3).

A.4.9.5 A period of at least 15 minutes should elapse between closing the valves or gates and opening the equipment to smother any residual fire in the equipment. As an added precaution, the equipment should be flooded with inert gas or steam, if available, prior to opening.

A.5.1 The normal handling temperature of liquid sulfur is 250°F to 309°F (121°C to 154°C), which is slightly above the melting point of 246°F (119°C). At the melting point sulfur is a transparent, mobile liquid. As the temperature of the liquid is raised, it darkens, becoming deep orange in hue. Up to about 320°F (160°C) the viscosity drops with rising temperature. Above this point the viscosity increases with rising temperature. At 370°F (188°C) the viscosity reaches a tremendously high maximum that practically prevents it from flowing and the liquid is so intensely colored as to be nearly opaque. Above 370°F (188°C) it again acts in a more normal fashion, with its viscosity falling somewhat as the temperature continues to rise.

At the normal handling temperature of liquid sulfur [250°F to 309°F (121°C to 154°C)] the vapor concentration above the pure sulfur, free of hydrocarbons or hydrogen sulfide, is too low to form a flammable mixture in air. While the flash point of liquid sulfur varies with purity, it is always higher than the normal handling temperature. For pure sulfur, the flash point can be as low as 370°F (188°C) and for relatively impure crude sulfur, the flash point can be as low as 334°F (168°C).

The relative low ignition temperature of sulfur and the possible presence of hydrogen sulfide are the primary fire and explosion hazards of liquid sulfur. Impure sulfur (sometimes referred to as "dark sulfur") contains hydrocarbons, which react slowly with the liquid sulfur to form hydrogen sulfide. Recovered sulfur, such as that produced from petroleum gas streams containing the hydrogen sulfide using the Claus Process, often contain dissolved hydrogen sulfide, which will be liberated slowly from a quiescent body of liquid sulfur. Agitation of such liquid sulfur will cause rapid evolution of hydrogen sulfide, which can create a flammable atmosphere within the storage tank. In the temperature range at which the liquid sulfur is normally handled, the lower flammable limit for hydrogen sulfide is at about 3.4 percent compared to 4.3 percent at room temperature.

Pure sulfur will not generate a flammable atmosphere in the normal temperature range of the liquid. Transfer of liquid sulfur using air pressure should be avoided. If air pressure is applied to the vapor space of an enclosure containing molten sulfur with high concentrations of hydrogen sulfide, there is a danger that the hydrogen sulfide/air mixture will become flammable. Transfer by pressure should be restricted to using an inert gas. Use of pumps would be the preferred transfer method.

Because impurities can cause generation of H_2S or pyrophoric iron sulfides, testing a representative sample of incoming batches for carbon content and hydrogen sulfide should be performed. These impurities should be kept to a minimum.

A.5.2.1 The sensing elements of some explosimeters are not designed for and are adversely affected by hydrogen sulfide–containing atmospheres.

A.5.3.3 See NFPA 77 for information on the subject.

A.5.3.4 Pyrophoric iron sulfide compounds can form from impurities in the sulfur. When heating coils are exposed to air, ignition can occur.

A.5.3.5 Due to the potential for release of dissolved hydrogen sulfide, molten sulfur handling systems require a Class I, Group C, classification for confined areas.

A.5.5.1(2) The steam should preferably be introduced near the surface of the molten sulfur. See NFPA 86, Section F.3.

A.5.5.1(3) For enclosed sulfur tanks or sulfur pits with air sweep systems designed to meet the requirements of NFPA 69, the sealing steam should be fed into the enclosure very near the air inlets. For such sulfur tanks and sulfur pits the use of a steam rate of 1.0 lb/min (0.45 kg/min) of steam per 100 ft^3 (2.83 m^3) of total tank or pit volume is expected to develop a positive pressure in the enclosure, thereby sealing the sulfur tank or sulfur pit and preventing air ingress and extinguishing the fire.

As the sealing steam vents backwards through the air inlets the sealing steam will quickly stop air ingress to the fire. Sealing steam should be fed into the sulfur tank or sulfur pit for a minimum of 15 minutes or until the temperature has returned to near normal. For further information and good engineering practice regarding sealing steam, see Mosher et al., *Molten Sulfur Fire Sealing Steam Requirements*.

A.7.1.1 It is recommended that the interior of size reduction and packaging rooms or buildings be painted a color that contrasts with the color of the dust.

A.7.2.1.1 Housekeeping for fugitive dusts is most important where the operational intent is that the dust accumulations are not normally present in the occupancy and the building has no deflagration protection features, such as damage limiting/explosion venting construction or classified electrical equipment, and additional personal protection from dust deflagration hazards also is not provided. Factors that should be considered in establishing the housekeeping frequency include:

(1) Variability of fugitive dust emissions
(2) Impact of process changes and non-routine activities
(3) Variability of accumulations on different surfaces within the room (walls, floors, overheads)

A.7.2.1.2 Unscheduled housekeeping in operating plants should be performed in accordance with Table A.7.2.1.2(a) to limit the time that a local spill or short-term accumulation of dust is allowed to remain before cleaning of the local area to less than the threshold dust accumulation. If the local spill occurs less than the indicated time before the end of the operating period, the spill should be cleaned prior to the next operating period.

Table A.7.2.1.2(b) shows approximate equivalent depths for the accumulation values in Table A.7.2.1.2(a) where the threshold dust accumulation is 0.2 lb/ft^2 (1 kg/m^2). The owner/operator can use an approximate depth to facilitate communication of housekeeping needs.

A.7.2.2.2 Push brooms should have natural bristles.

A.7.2.2.4 Because the mixture of sulfur dust and water can corrode materials of construction, the use of steam is discouraged. All the listed precautions might not be required for limited use of compressed air for cleaning minor accumulations of dust from machines or other surfaces between shifts.

A.8.3.2(8) All plant personnel, including management, supervisors, and maintenance and operating personnel, should be trained to participate in plans for controlling plant emergencies. Trained plant fire squads or fire brigades should be maintained.

The emergency plan should contain the following elements:

(1) A signal or alarm system
(2) Identification of means of egress
(3) Minimization of effect on operating personnel and the community
(4) Minimization of property and equipment losses
(5) Interdepartmental and interplant cooperation
(6) Cooperation of outside agencies
(7) The release of accurate information to the public

Simulated emergency drills should be performed annually by plant personnel. Malfunctions of the process should be simulated and emergency actions undertaken. Disaster drills that simulate a major catastrophic situation should be undertaken periodically with the cooperation and participation of public fire, police, and other local community emergency units and nearby cooperating plants.

A.8.5.1.1 Qualified contractors should have proper credentials, which include applicable American Society of Mechanical Engineers (ASME) stamps or professional licenses. [**654:** A.11.5.1.1]

A.8.5.4 It is suggested that annual meetings be conducted with regular contractors to review the facility's safe work practices and policies. Some points to cover include to whom the contractors would report at the facility, who at the facility can authorize hot work or fire protection impairments, and smoking and nonsmoking areas. [**654:**11.5.4]

A.9.1.2(5) Process interlocks should be calibrated and tested in the manner in which they are intended to operate, with written test records maintained for review by management. Testing frequency should be determined in accordance with the AIChE *Guidelines for Safe Automation of Chemical Processes.*

A.9.2.2.4 Periodic cleaning of components is especially important if the blower or fan is exposed to heated air.

A.9.2.2.5 If rust is allowed to form on the interior steel surfaces, it is only a matter of time before an iron oxide (rust) becomes dislodged and is taken downstream, striking against the duct walls. In some cases, this condition could cause an ignition of combustibles within the duct. The situation worsens if aluminum paint is used. If the aluminum flakes off or is struck by a foreign object, the heat of impact could be sufficient to cause the aluminum particle to ignite, thereby initiating a fire downstream.

Table A.7.2.1.2(a) Unscheduled Housekeeping in Operating Plants

Accumulation on Worst Single Square Foot (Square Meter) of Surface	Longest Time to Complete Unscheduled Local Cleaning of Floor-Accessible Surfaces	Longest Time to Complete Unscheduled Local Cleaning of Remote Surfaces
> 1 to 2 times threshold dust mass/accumulation	8 hours	24 hours
>2 to 4 times threshold dust mass/accumulation	4 hours	12 hours
>4 times threshold dust mass/accumulation	1 hour	3 hours

Table A.7.2.1.2(b) Unscheduled Housekeeping in Operating Plants

Accumulation on Worst Single Square Foot (Square Meter) of Surface		Average Depth at 75 lb/ft^3 (1200 kg/m^3)	
lb/ft^2	kg/m^2	lb/ft^2	kg/m^2
0.2 to 0.4 lb/ft^2	>1 to 2 kg/m^2	>1⁄16 in. to 1⁄8 in.	1.7 to 3.3 mm
0.4 to 0.8 lb/ft^2	>2 to 4 kg/m^2	>1⁄8 in. to 1⁄4 in.	3.3 to 6.4 mm
0.8 lb/ft^2	>4 kg/m^2	>1⁄4 in.	6.4 mm

Annex B Dust Layer Characterization and Precautions

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

B.1 The threshold mass equations in 4.2.5 provide a means to determine whether the normal accumulation of combustible dust in the building/room requires the addition of a safeguard for workers in the immediate area or a safeguard for workers remote from the immediate area. This is similar to the concept of maximum allowable quantity in control areas in building codes. Above the maximum quantity, the area is considered hazardous and additional safeguards are required. Chapter 6 of *NFPA 5000* indicates that where combustible dusts are stored, used, or generated in a manner creating a severe fire or explosion hazard the building/room is considered to contain high hazard Level 2 contents.

This standard acknowledges that accumulation of combustible dust outside of equipment can present a severe hazard when the quantity exceeds certain thresholds. When the threshold is exceeded, this standard imposes physical barriers and explosion venting to limit and control the explosion hazard as well as personal protective equipment and fire separations to address the flash-fire hazard.

In addition to the many process design constraints intended to limit ignition potential, the use of proper electrical equipment is addressed separately. It is important to recognize that the criteria for requiring electrically classified equipment are different from the thresholds for flash-fire or explosion hazard. As an example, in a single room the total dust accumulation could be large enough that the entire room is deemed an explosion hazard area, yet if the dust accumulation is evenly distributed, it is possible that electrically classified equipment is not needed. Conversely, there could be an isolated area with thick layers of dust that would require the installation of electrically classified equipment, and yet the room, in total, does not contain sufficient dust accumulation to exceed the threshold mass.

The user can apply Equation 4.2.5.1 and Equation 4.2.5.2 to separately determine if an explosion hazard or a flash-fire hazard exists from total accumulated dust mass in the building/room. If so, then safeguards are required for workers remote from the area or in the immediate area, respectively.

The basic equations in 4.2.5.1 and 4.2.5.2 do not require measurement of any physical or combustibility properties for application. They are independent of those properties and offer a generally conservative approach. The only variables are the total building/room floor area and the general height of the building/room, which provides a volume correction. In practice, the user can weigh the amount of accumulated dust in various areas outside of equipment to estimate the total dust mass in the building/room. If the dust mass exceeds the threshold determined according to 4.2.5.1, then the area is a dust explosion hazard area. If the dust mass exceeds the threshold determined according to 4.2.5.2, then the area is a dust flash-fire hazard area. Depending on building height, the area of dust accumulation could be a dust explosion hazard area, a dust flash-fire hazard area, or both.

An example application is a 10,764 ft² (1000 m²) building having a peaked roof with eave height of 30 ft (9 m) and peak height of 33 ft (10 m). The owner/user expects only minor dust accumulation near certain activities and has provided electrically classified equipment in these limited areas. When operations began, a routine housekeeping schedule was documented and instituted to minimize dust accumulation. After 2 months of operation, the owner/user weighs dust samples from six different areas in the plant, as listed below in Table B.1.

Based on the weighed samples, the owner/user multiplies the mass per unit area by the estimated floor area for the samples and estimates the weight of dust in each section of the plant. As a result, the owner/user determines that practicable housekeeping has allowed the dust to accumulate to about 132 lb (60 kg) over the building. According to Equations 4.2.5.1 and 4.2.5.2, the threshold masses are 209 lb (95 kg) for an explosion hazard area and 110 lb (50 kg) for a flash-fire hazard area:

[B.1]

$$M_{basic-exp} = 0.01 \cdot A_{floor} \cdot H$$

$$M_{basic-exp} = 0.01 \cdot 1000\ \text{m}^2 \cdot 9.5\ \text{m} = 95\ \text{kg}$$

$$M_{basic-fire} = 0.05 \cdot A_{floor}$$

$$M_{basic-fire} = 0.05 \cdot 1000\ \text{m}^2 = 50\ \text{kg}$$

Thus practicable housekeeping has resulted in too much dust without additional safeguards for the flash-fire hazard, and the owner/user would have to consider Chapter 8 to determine appropriate PPE needs or modify equipment to better contain the dust. In this example, current housekeeping is sufficient to discount an explosion hazard. The user could decide to proceed with the results of the basic equations without further evaluation or to use the method in 4.2.5.3.

Since the original design of the building presumed which areas would experience dust accumulation outside equipment, the owner/user should review the electrical area classification against the actual locations of accumulations, based on NFPA 499.

B.2 The dust accumulation is a product of the actual layer depth and the total area of accumulation. The limitation in 4.2.5.3.3 is expressed as a product of the layer depth criterion and a percentage of the footprint area of the room or building. Within a single room or building, areas of significant dust accumulation could be contiguous or separated. Where they are separated, the separate accumulations are combined and compared to the permissible dust accumulation. The layer depth criterion can be increased for a specific dust when the bulk density is known.

Table B.1 Example Data Table

	Floor Area		Above-Floor Area		Sampled Area		Sampled Weight		Estimated Weight	
Section Name	**m²**	**ft²**	**m²**	**ft²**	**m²**	**ft²**	**kg**	**lb**	**kg**	**lb**
Bag unloading	20	215	—	—	2	22	0.5	1.1	5	11
Processing	600	6458	—	—	4	43	0.05	0.011	7.5	16.5
Packaging	180	1938	—	—	3	32	0.65	1.43	39	86
Shipping	200	2153	—	—	4	43	0.05	0.011	2.5	5.5
Bar joist	—	—	50	538	2	22	0.1	0.22	2.5	5.5
Mezzanine	—	—	105	1130	3	32	0.1	0.22	3.5	7.7
Total	1000	10764	N/A	N/A	N/A	N/A	N/A	N/A	60	132

For rooms or buildings where dust accumulations are limited to a small area, one way to determine if the actual dust accumulation is sufficient to result in a dust deflagration hazard is to ratio the actual dust accumulation to the permissible dust accumulation. If the ratio exceeds 1, then a dust deflagration hazard exists in the subject building or room.

Surfaces where dust could settle include floors, beam flanges, piping, ductwork, equipment, suspended ceilings, light fixtures and walls. Because dust adhering to walls and vertical surfaces can be easily dislodged, particular attention should be given to these surfaces.

When the total volume of dust accumulations is being determined, accumulation areas where the underlying surface colors are readily discernible can be excluded.

Example 1: A single floor accumulation area in a small portion of a 25 ft by 40 ft (7.62 m by 12.2 m) room. The dust has a bulk density of 75 lb/ft^3 (1200 kg/m^3).

Layer depth criterion = $\frac{1}{32}$ in. (0.8 mm)

Room footprint area = 1000 ft^2 (93 m^2)

Actual accumulation area = 20 ft^2 (1.86 m^2)

Average layer depth in accumulation area = $\frac{1}{16}$ in. (1.6 mm)

[B.2a]

$$Ratio = \frac{20\ \text{ft}^2 \cdot \frac{1}{16}\ \text{in.}}{0.05 \cdot 1000\ \text{ft}^2 \cdot \frac{1}{32}\ \text{in.}} = \frac{1.3\ \text{ft}^2 \cdot \text{in.}}{1.6\ \text{ft}^2 \cdot \text{in.}} \leq 1$$

Since the ratio is less than or equal to 1, a dust deflagration hazard does not exist in the room. Where the actual accumulation area is less than 5 percent of the room footprint, the layer thickness can be greater without resulting in a dust deflagration hazard.

Example 2: A single floor accumulation area in a portion of a 25 ft by 40 ft (7.62 m by 12.2 m) room. The dust has a bulk density of 30 lb/ft^3 (481 kg/m^3). First adjust the layer depth criterion for the reduced bulk density:

[B.2b]

$$Layer\ Depth\ Criterion = \frac{\frac{1}{32}\ \text{in.} \cdot 75\ \text{lb/ft}^3}{30\ \text{lb/ft}^3} = 0.078\ \text{in.} \cong \frac{1}{16}\ \text{in.}$$

Room footprint area = 1000 ft^2 (93 m^2)

Actual accumulation area = 100 ft^2 (9.3 m^2)

Average layer depth in accumulation area = $\frac{1}{32}$ in. (0.8 mm)

[B.2c]

$$Ratio = \frac{100\ \text{ft}^2 \cdot \frac{1}{32}\ \text{in.}}{0.05 \cdot 1000\ \text{ft}^2 \cdot 0.78\ \text{in.}} = \frac{3.1\ \text{ft}^2 \cdot \text{in.}}{3.9\ \text{ft}^2 \cdot \text{in.}} \leq 1$$

Since the ratio is less than or equal to 1, a dust deflagration hazard does not exist in the room. A dust with a bulk density less than the basis of 75 lb/ft^3 (1200 kg/m^3) can accumulate to $\frac{1}{32}$ in. (0.8 mm) layer depth in more than 5 percent of the room footprint area and still not present a dust deflagration hazard.

Example 3: Multiple floors and elevated accumulation areas with different layer depths for each area. The room is 100 ft by 100 ft (30.5 m by 30.5 m). For rooms less than 20,000 ft^2 (1858 m^2), the limitation is based on a maximum of 5 percent of the footprint area. The dust has a bulk density of 30 lb/ft^3 (481 kg/m^3). First, adjust the layer depth criterion for the reduced bulk density:

[B.2d]

$$Layer\ Depth\ Criterion = \frac{\frac{1}{32}\ \text{in.} \cdot 75\ \text{lb/ft}^3}{30\ \text{lb/ft}^3} = 0.078\ \text{in.} \cong \frac{1}{16}\ \text{in.}$$

Room footprint area = 10,000 ft^2 (929 m^2)

[B.2e]

$$Ratio = \frac{50\ \text{ft}^2 \cdot \frac{1}{16}\ \text{in.} + 500\ \text{ft}^2 \cdot \frac{1}{32}\ \text{in.} + 100\ \text{ft}^2 \cdot \frac{1}{8}\ \text{in.}}{0.05 \cdot 10{,}000\ \text{ft}^2 \cdot 0.78\ \text{in.}}$$
$$= \frac{31\ \text{ft}^2 \cdot \text{in.}}{39\ \text{ft}^2 \cdot \text{in.}} \leq 1$$

Since the ratio is less than or equal to 1, a dust deflagration hazard does not exist in the room. There could be more separated accumulation areas than are listed in Table B.2, and all significant areas should be included. Note that areas where dust layers are such that the underlying surface colors are readily discernible would not be included.

Where there is a single accumulation area or the actual layer depth is the same over all accumulation areas, Figure B.2 indicates the actual layer depth that results in a dust deflagration hazard.

B.3 While the threshold mass equations consider all of the dust mass throughout the building, it is not anticipated that the dust will be evenly distributed. Rather, there will be localized areas of accumulation where fugitive dust is not completely captured. If the threshold mass of dust were actually evenly distributed, it would typically be an extremely thin layer. Such a layer would be too thin to create a hazard because the entrainment fraction would be much smaller, and only a small portion of the dust mass would actually be involved in the event. The inclusion of all accumulated dust mass is conservative in this respect.

Where processing areas are segregated by walls and the entries are self-closing, this can be used to limit the area where the user has to apply safeguards against a flash-fire hazard. Similarly, where segregating walls and entries are also pressure resistant, this can be used to limit the area where the user has to apply safeguards against an explosion hazard. Where a multi-

Table B.2 Multiple Accumulation Areas for Example 3

Accumulation Location	Accumulation Area (ft^2)	Average Layer Depth (in.)	Accumulation (ft^2 · in.)
Floor	50	$\frac{1}{16}$	3.1
Beam surfaces	500	$\frac{1}{32}$	15.6
Equipment surfaces	100	$\frac{1}{8}$	12.5

Note: For SI units, 1 in. = 25.4 mm, 1 ft^2 = 0.093 m^2.

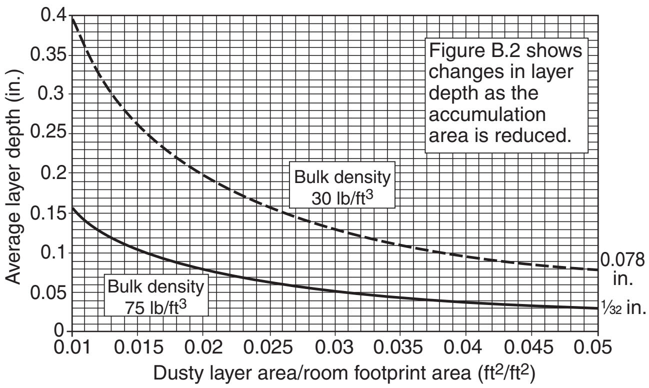

FIGURE B.2 Dust Deflagration Hazard Limitation — Average Layer Depth with Reduced Accumulation Area for Buildings or Rooms.

floor building is effectively segregated by intervening floors, explosion and flash-fire hazards can be evaluated on a floor-by-floor basis.

Where there are open mezzanines above a floor level, the accumulated dust on these levels is added to that on the main level without increasing the floor area.

When the total dust mass in a building or room is being determined, due consideration should be given to dust that adheres to walls, since it is easily dislodged. Attention and consideration should also be given to other projections, such as light fixtures, that can provide surfaces for dust accumulation.

Dust collection equipment should be monitored to ensure that it is operating effectively. For example, dust collectors that use bags operate most effectively between limited pressure drops of 2 in. to 5 in. of water (0.50 kPa to 1.24 kPa). An excessive decrease or low drop in pressure indicates insufficient coating to trap dust.

Annex C Informational References

C.1 Referenced Publications. The documents or portions thereof listed in this annex are referenced within the informational sections of this standard and are not part of the requirements of this document unless also listed in Chapter 2 for other reasons.

C.1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, 2013 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 2014 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 2014 edition.

NFPA 86, *Standard for Ovens and Furnaces*, 2015 edition.

NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*, 2017 edition.

NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 2017 edition.

NFPA 652, *Standard on the Fundamentals of Combustible Dust*, 2016 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, 2017 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems*, 2017 edition.

NFPA 5000®, Building Construction and Safety Code®, 2015 edition.

C.1.2 Other Publications.

C.1.2.1 AIChE Publications. American Institute of Chemical Engineers, 120 Wall Street, Floor 23, New York, NY 10005-4020.

Guidelines for Safe Automation of Chemical Processes, 1993.

C.1.2.2 ASTM Publications. ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM D257, *Standard Test Methods for DC Resistance or Conductance of Insulating Materials*, 2014.

ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, 2014.

ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, 2007.

ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air,* 2007, reapproved 2013.

C.1.2.3 IEC Publications. International Electrotechnical Commission, 3, rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland.

IEC 62305-2, *Protection Against Lightning — Part 2: Risk Management*, 2010.

C.1.2.4 Other Publications. Britton, L., *Avoiding Static Ignition Hazards in Chemical Operations,* CCPS, New York, NY, 1999, pp. 199–204.

Ebadat, V., and Mulligan, J. C., "Testing the Suitability of FIBCs for Use in Flammable Atmospheres," *Process Safety Progress,* Vol. 15, No. 3, 1996.

Eckhoff, R. K., *Dust Explosions in the Process Industries,* Oxford, UK: Butterworth-Heinemann Ltd., 3rd edition, 2003.

Mosher, A. D., McGuffie, S. M., and Martens, D.H., *Molten Sulfur Fire Sealing Steam Requirements*, Brimstone Sulfur Symposium, Vail CO., September 2015.

C.2 Informational References. The following documents or portions thereof are listed here as informational resources only. They are not a part of the requirements of this document.